METHOD AND APPARATUS USING A MULTI-CARRIER FORWARD LINK IN A WIRELESS COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

1. Field Of the Invention

The present invention relates to communications. More particularly, the invention concerns a method and apparatus for transmitting information in a wireless communication system.

2. Description of the Related Art

Figure 1 illustrates a portion of the radio frequency spectrum used in a common telecommunications system. Frequency range 100 centered around 800 MHz has historically been known as the cellular frequency range and frequency range 102 centered about 1900 MHz is a newer defined frequency range associated with personal communication services (PCS). Each range of frequencies, i.e., the cellular and PCS, are broken into two portions. In the cellular frequency range 100, there is a reverse link portion 104 that is used for communications from a mobile communication device to a base station such as a cellular base station. Portion 106 of cellular frequency range 100 is used for forward link communications, that is, communications from a cellular base station to a mobile communication device. In a similar fashion, portion 108 of PCS frequency range 102 is used for reverse link communications, that is, communications from a mobile communication device to a base station. Portion

110 of PCS frequency range 102 is used for reverse link communications, i.e., communications from a base station to a mobile communication device.

Each of the frequency ranges is broken into bands that are typically associated with different service providers. In the case of cellular frequency range 100, frequency bands 112 and 114 are designated band "A" for reverse link and forward link communications, respectively. A reverse link is the band connecting a mobile station to a base station, and a forward link is the band connecting a base station with a mobile station. In a particular geographic area, a cellular service provider is assigned frequency band "A" in order to carry out mobile communications. Likewise, in the same geographic area another cellular service provider is assigned frequency bands 116 (for forward link communications) and 118 (for reverse link communications) which are designated band "B". The transmit and receive frequencies are separated by 45 MHz and with the minimum separation between transmit and receive bands is 20 MHz. This minimum separation is to avoid interference between the forward and reverse links and to permit diplexers, which separate the forward and reverse link signals in a mobile station to be used.

A few years ago, the US Government auctioned the PCS frequency spectrum to service providers. As with the cellular frequency range, the PCS frequency range is broken into several bands where a different service provider may use a particular frequency band for which it is licensed within a particular geographical area. The PCS bands are referred to as A, B, C, D, E and F. The A

band includes reverse link band 120 and forward link band 122. The B band includes reverse link band 124 and forward link band 126. Band C includes reverse link band 128 and forward link band 130. The reverse link and the forward link band of A, B and C bands are each 15 MHz wide. The D band includes reverse link band 132 and forward link band 134. The E band includes reverse link band 136 and forward link band 138. Likewise, band F includes reverse link band 140 and forward link band 142. The reverse link and forward link bands of D, E and F are each 5 MHz wide. Each of the different cellular and PCS bands can support a number of communications carriers in both the reverse link and forward link direction.

As shown in Figure 1, it is possible to have as many as eight different wireless communication service providers in a particular area - two cellular service providers, each having a total allocated bandwidth of 25 MHz (forward and reverse links), and six PCS service providers, each having a total allotted bandwidth of 30 MHz for the A, B, and C blocks or 10 MHz for the D, E, and F blocks. These providers may employ different technologies for transmitting and receiving telephone calls, data, control commands, or other types of information, singularly and collectively referred to in this application as information signals. For example, a time-division-duplexing technique, a frequency-division-duplexing technique, or a code-division-multiple-access (CDMA) technique might be employed by a provider as described below. Further, if the carrier is using CDMA, then various CDMA releases are available such as IS-95-A and IS-95-B.

Recently, in response to consumers demand for greater service options, the International Telecommunications Union (ITU) solicited proposals for Third Generation wireless communications. The Third Generation Proposals strive to expand the capabilities of the preceding technologies to include wireless e-mail, Web browsing, and corporate and local network access, as well as videoconferencing, e-commerce and multimedia. One of the candidate submissions to the ITU was proposed by subcommittee TR45.5 of the Telecommunications Industry Association (TIA) and was called cdma2000, which has since been developed and continues to be developed under the name of IS-2000. The proposed cdma2000 system includes three modes of operation: 1X, 3X direct spread (DS) and 3X multi-carrier (MC). Each of these modes can be operated in frequency division duplex (FDD) or time-division duplex (TDD) manner.

The 1X FDDmode operates within a 1.25 MHz bandwidth on both the forward and reverse links, thereby providing for higher capacity in the 1.25 MHz bandwidth and supporting high-speed data transmissions. The spreading rate is 1.2288 Mcps on both the forward and reverse links of 1X systems. The 3X FDDmode operates within a 3.75 MHZ band on both forward and reverse links. The 3X mode forward link employs either a direct spread or a multi-carrier transmission format. In the 3X direct spread mode, a single forward link carrier with a chip rate of 3.6864 Mcps is used; in the 3X multi-carrier mode, the forward link consists of three carriers that are each spread at a spreading rate of

1.2288Mcps. The 1X TDD mode operates within a single 1.25 MHz bandwidth for both the forward and reverse links. The 3X direct spread and multi-carrier TDD modes operates within a single 3.75 MHz for both the forward and reverse links.

By using the 3X FDD mode and providing a forward link using the multi-carrier format, a communications system is fully compatible with existing IS-95 system. That is, the cdma2000 forward link structure may be "over-laid" on existing PCS systems. One attribute that makes the forward link multi-carrier system compatible with existing systems is that it preserves orthogonality of signals transmitted in the forward link. The reverse link is not orthogonal, so cdma2000 systems use a direct spreading to 3.6864 Mcps. When used, the time-division-duplex (TDD) mode of operation allows both the forward link and reverse link to be transmitted in a single 1.25 MHz band. The TDD forward link is transmitted in a first time interval and the TDD reverse link is transmitted in a non-overlapping second time interval. The transmissions in both time intervals are direct spread at a 1.2288 Mcps spreading rate.

As mentioned above, Third Generation Systems such as cdma2000 3X are designed for transmitting information that may have very high data transfer requirements, such as email downloading and web browsing. For example, a mobile station user may send a simple message requesting that a page from web site be downloaded to his mobile phone. This simple request requires very

little bandwidth when transmitted on the reverse link to the base station, but timely downloading of the web site on the forward link from the base station to the mobile station will require substantial bandwidth. A request for a page may be in the order of a few hundred bytes, but the response from the web server can be several tens of thousands of bytes, particularly if it includes graphics or pictures. However, in the currently proposed Third Generation Systems, the bandwidth allocated to reverse link transmissions is the same as the bandwidth allocated for forward link transmissions.

What is needed is a method and apparatus that will allow for the bandwidth allocated to the forward link to be different than the bandwidth allocated for the reverse link. One version of the method and apparatus should provide for better spectrum management. Further, the method and apparatus should allow the user of a technology such as cdma2000 1X to easily transition to a newer version of the technology, such as cdma2000 3X.

SUMMARY OF THE INVENTION

Broadly, the present invention relates to wireless communications. More particularly, the invention concerns forward link and reverse link designs utilized in a wireless telecommunications system. In various embodiments, the invention allows a system using the 1X mode of cdma2000 to easily migrate to using a 3X mode of cdma2000. In other embodiments, the invention provides for better spectrum management, and allows the bandwidth used in the

forward link to vary from the bandwidth in the reverse link. The invention also provides for less unwanted emissions, thus permitting more effective utilization of the bandwidth.

In one embodiment, the present invention provides a method that improves spectrum use. With the method, a single cdma2000 1X reverse link (1X RL) is used in conjunction with a cdma2000 3X forward link (3X FL). The 3X FL has three 1.2288 Mcps carriers and the 1X RL uses one 1.2288 Mcps carrier. The 3X FL carriers may occupy adjacent "frequency bins" as described below, or the bins might not be adjacent. In an exemplary embodiment where the 3X carrier bins are adjacent, the 1X carrier bin may be located in the center frequency bin range. In other embodiments, it may be located at anyone of the three frequencies. In general, it can be located anywhere within a providers allotted frequency band, or where allowed by multiple providers, anywhere within the frequency spectrum for the cellular or PCS spectrum. In another embodiment, the 3X FL carrier uses one or more carriers with a chip rate that is greater than the chip rate used on the 1X RL carrier.

In another embodiment, the invention provides an article of manufacture containing digital information executable by a digital signal-processing device. In another embodiment, the invention yields an apparatus used to practice the methods of the invention. The apparatus may comprise a remote station and at least one base station that has, amongst other things, a transceiver used to communicate information signals to the remote station. Obviously, to receive

signals, the remote station also includes a transceiver which transmits and receives from the base station, and possibly satellites where applicable. The apparatus will also include at least one digital processing apparatus, such as a microprocessor, that is communicatively coupled to the network or one of its component parts.

The invention provides its users with numerous advantages. One advantage is that it provides better spectrum management to a service provider. Another advantage is that a cdma2000 1X system can be upgraded to cdma2000 3X system services on an incremental basis if desired without having to entirely replace existing hardware at once. As explained below, additional hardware can be added to provide particular types of service as demand for those service types increase. This allows a provider to economically supply only those services that its users demand. The invention also provides a number of other advantages and benefits that should become even more apparent after reviewing the following detailed descriptions of the invention.

BRIEF DESCRIPTION OF THE DRAWING

The nature, objects, and advantages of the invention will become more apparent to those skilled in the art after considering the following detailed description in connection with the accompanying drawings, in which like reference numerals designate like parts throughout, and wherein:

FIGURE 1 illustrates the frequency spectrum used for wireless communications;

FIGURE 2 shows a cdma2000 3X multi-carrier forward link and a single cdma2000 1X reverse link used in accordance with the invention;

FIGURE 3 shows a grouping in a band of CDMA reverse links that allows room in the band for TDD channels used in accordance with the invention;

FIGURE 4a is a block diagram of a general configuration for a mobile station used in accordance with the invention;

FIGURE 4b is a block diagram of a general channel structure used in accordance with the invention;

FIGURE 5a is a block diagram of a portion of the hardware components and

interconnections of a digital signal processing apparatus used in accordance with the invention;

FIGURE 5b shows an exemplary arrangement for a demultiplexer 511 shown in Figure 5a and used in accordance with the invention;

FIGURE 5c shows another arrangement for a demultiplexer 511 shown in Figure 5a and used in accordance with the invention;

FIGURE 5d is a block diagram of the hardware components and interconnections of a digital signal processing apparatus used in accordance with the
invention;

FIGURE 5e is a block diagram of the hardware components and interconnections of the modulator 526 shown in Figure 5d and used in accordance with the invention;

FIGURE 6a is a block diagram of a portion of the hardware components and
interconnections of a digital signal processing base station apparatus used in accordance with the invention; and

FIGURE 6b is a block diagram of the hardware components and interconnections of the demodulator 604 shown in Figure 6a and used in accordance with the invention.

FIGURE 7 is a diagram showing the spectrum of a 1X and a 3X reverse link spectrums.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

OPERATION

Figures 2- 6b illustrate examples of various method and apparatus aspects of the present invention. For ease of explanation, but without any limitation intended, these examples are described in the context of a digital

signal processing apparatus, one example of which is described following the discussion of the various method embodiments below.

An exemplary embodiment of the present invention is based upon a CDMA system. CDMA systems are disclosed in TIA/EIA/IS-2000, prepared by the Telecommunications Industry Association, entitled "SPREAD SPECTRUM DIGITAL TECHNOLOGY - MOBILE AND PERSONAL COMMUNICATIONS STANDARDS," and TIA/EIA/IS-95-x entitled "MOBILE STATION-BASE STATION COMPATIBILITY STANDARD FOR DUAL-MODE WIDEBAND SPREAD SPECTRUM CELLULAR SYSTEM", all of which are incorporated by reference herein. As disclosed in IS-2000, a standard cdma2000 3X multi-carrier (MC) forward link (FL) system uses three 1.2288 Mcps carriers paired with a reverse link (RL) that uses a single 3X carrier. This single carrier provides a direct spread chip rate of 3.6864 Mcps. The present invention improves upon this normal configuration.

It should be understood that the methods of the present invention as disclosed below apply to a broad range of services. These services include voice and data services, but the invention is particularly suitable for data services, such as email and Web browsing, which typically have a significantly greater FL load requirement than RL load requirement.

Spectrum Management

In one embodiment, the invention uses a cdma2000 MC FL and a single cdma2000 1X reverse link as illustrated in Figure 2. For a cdma2000 PCS configuration, each MC FL carrier is separated by 1.25 MHz. In the figure, the 1X RL carrier is shown in a center "frequency bin," wherein the term frequency bin describes a 1.25 MHz band within a band class. However, in other embodiments, the 1X RL carrier could be located in any one of the three possible frequency bins corresponding to each of the three MC FL frequencies. In the example of Figure 2, the three possible bins have center frequencies for each carrier of 1.25 MHz, 2.5 MHz, and 3.75 MHz respectively. The 3X MC FL is centered at 2.5 MHz. In other embodiments, the 1X RL carrier may be in any frequency bin allocated to a provider.

As is known in the art and discussed below, a mobile station can transmit the 1X RL on any frequency within a provider's band. There are a number of well-known ways that can be used to generate the different RL frequencies. The small geometries being used for digital signal processing devices, such as semiconductors, permit the use of high clock rates with relatively low power consumption. Thus, it is quite practical to generate an RL waveform that can be varied over the bandwidth allocated to a provider. In particular, it is quite simple to generate the three bins described above. One benefit of this invention is that there really isn't any change in the physical layer structure of the cdma2000 1X technique to implement the invention, wherein

physical layer refers to the communication protocol between a mobile station and a base station that is responsible for the transmission and reception of data. For example, a power control signal for RL power control can be sent on the three FL multi-carriers and the power control stream for FL power control can be sent on a single RL carrier.

By moving the cdma2000 1X RL over a wide frequency range, and the asymmetric structure that results, the RLs can be grouped in one part of the frequency band and the FLs in another part of the frequency band. This allows for novel and previously undiscovered opportunities in spectrum management. One such arrangement is shown in Figure 3. Here, the RLs are grouped together, leaving room in the provider's band to use 1X and 3X FDD channels and 1X time-division-duplexed (TDD) channels. It should be noticed that the TDD usage is on the RL where interference issues will be less problematic than the other way around, particularly if FDD service is considered the more important service. The separation of frequency bands between the FDD and the TDD service is sufficient to provide little interference between the FDD and TDD services. Accordingly, the TDD mobile station transmitter may be using the same frequency band as the FDD base station transmitter if there is sufficient frequency separation between the mobile station and the base station. Figure 7 shows the emissions for both 1X and 3X reverse links from a mobile station. Ideally, the transmitted spectrums would be exactly the bandwidth of 1.2288 MHz for 1X or 3.6864 MHz for 3X. However, intermodulation distortion in the transmitter causes unwanted emissions. As can be seen in Figure 7, the

pedestal due to intermodulation distortion in the transmitter is significantly broader in bandwidth with a 3X reverse link than a 1X reverse link. The close in pedestal is due to 3rd order intermodulation products; the farther out pedestal is due to 7th order intermodulation products. The bandwidth of each pedestal is approximately equal to the chip rate. Thus, the bandwidth of the 3X reverse link including the 3rd order pedestal is approximately three times the chip rate, or 11.0592 MHz. In contrast, the bandwidth of the 1X reverse link including the 3rd order pedestal is approximately three times the chip rate, or 3.6864 MHz. The intermodulation distortion can be reduced (and thus the unwanted emissions can be reduced) by having a more linear power amplifier. However, a more linear power amplifier in the mobile station requires more battery power for the same power output. Since a design goal of a mobile station is to have a long battery life, there is a tradeoff between unwanted emissions and battery life. As is easily understood from the discussion, the 3X waveform has much broader emissions in terms of bandwidth which results in a greater guardband to TDD and other systems. While emissions from the base station are also a concern, base stations usually don't use batteries as their main power source. Thus, having a more linear power amplifier is significantly less difficult than in a mobile station.

Forward Link Distribution by Data Type

In one embodiment of the proposed invention using a cdma2000 MC FL transmission system, each of the channels of information is evenly distributed across each of the three carriers of the forward link. For example, when

transmitting a data signal on the forward link, the symbols for that data signal are evenly distributed with a third of the symbols transmitted on each of the carriers. The benefit of this method is that is provides maximum frequency diversity and increases the reliability of the transmission of the signal. This method minimizes problems caused by frequency dependent propagation characteristics, such as fading.

However, using this even-distribution embodiment reduces the flexibility that a multi-carrier forward link can provide. Therefore, in another embodiment of the present invention, different types of information are transmitted using different carriers. For example, fundamental channel data such as speech data may be transmitted on a first carrier while supplemental channel data such as high-speed digital data is transmitted on a second carrier. This allows the system to be adapted to the needs of the area that it is serving and permits a service provider to incrementally increase the services provided to its customers.

For example, when a provider has a three-carrier FL system, he may elect initially to provide speech services on a 1X band. Later, in response to the needs of his customers, a second band can be deployed to carry additional speech services, or the band may be allocated to the purpose of carrying high-speed digital data. Thus, in this embodiment of the present invention, the bands are allocated to carrying different types of data.

In yet another embodiment, three cdma2000 1X FLs are provided on adjacent frequencies with a single cdma2000 1X RL. Unlike techniques used for multi-code transmissions, multiple FL code channels are assigned to a mobile station on different frequencies. Any combination of code channels can be used on the three frequencies. For example, a 307.2 kbps FL code channel can be supplied on each of the FL carriers, providing a total data rate of 921.6 kbps. In another embodiment, the spectrum management methods discussed in the previous section can be used with this method. In another arrangement, one of the forward link channels coveys power control information for the RL and a fundamental channel. A fundamental channel is generally a channel that carries voice, low speed rate, such as acknowledgements, and control information. Other frequencies can be used for supplemental channels that operate in conjunction with the fundamental channel, and/or possibly other channels, to provide higher data rate services.

These embodiments have the advantage that existing base station (BS) hardware may be used and, when necessary, supplemented with additional hardware to increase the forward link transmission rates. Supplementing existing hardware, as opposed to replacing an entire base station, is less expensive. Further, the methods of the present invention allow a provider to easily transition from a cdma2000 1X system to a cdma2000 3X system. However, in order to reuse existing BS hardware, some simplifications may be needed in various implementations. One such simplification is that fast (800 Hz) forward link power control used for controlling the transmission power on

one frequency probably cannot be used to control the transmit power on other frequencies. This situation arises if a particular BS design uses separate hardware cards for each frequency. Separate hardware cards would not permit the transfer of fast power control streams between frequencies in common configurations.

Further, for high-speed data channels, particularly channels with long interleavers, fast forward link power control is not always the best technique for controlling power if the goal is to maximize system capacity. Thus, in this embodiment, a slower form of power control, such as one widely known in the art, should be used. For example, one way of performing FL power control for these additional frequencies is to control the transmitted power from a selector, as is currently done with many IS-95 systems. There, algorithms in a selector determine when the power transmitted to a mobile station needs to be changed and sends the gain to the BS every frame. A more detailed description of the technique may be found in TIA/EIA/IS-634, entitled "MCS-BS INTERFACE (A-INTERFACE) FOR PUBLIC 800 MHZ," published by the Telecommunications Industry Association, and incorporated by reference herein.

As a result, fast forward power control can be used on one FL frequency which contains the fundamental, control channels, and perhaps some supplemental channels. Slow power control can be used on other FL frequencies which contain additional supplemental channels.

HARDWARE COMPONENTS AND INTERCONNECTIONS

A digital data processing apparatus used to execute a sequence of machine-readable instructions as mentioned above may be embodied by various hardware components and interconnections as described in Figures 4a-6b.

Figure 4a shows a simple block representation of a mobile station (MS) 401 configured for use in accordance with the present invention. MS 401 receives a signal from a base station (not shown) using a cdma2000 3X MC forward link. The signal is processed as described below. MS 401 uses a cdma2000 1X RL to transmit information to the base station.

Figure 4b shows a more detailed block representation of a channel structure used to prepare information for transmission by MS 401 in accordance with the present invention. In the figure, information to be transmitted, hereafter referred to as a signal, is transmitted in bits organized into blocks of bits. A CRC and tail bit generator (generator) 403 receives the signal. The generator 403 uses a cyclic redundancy code to generate parity check bits to assist in determining the quality of the signal when received by a receiver. These bits are included in the signal. A tail bit - a fixed sequence of bits - may also be added to the end of a block of data to reset an encoder 405 to a known state.

The encoder 405 receives the signal and builds a redundancy into the signal for error-correcting purposes. Different "codes" may be used to

determine how the redundancy will be built into the signal. These encoded bits are called symbols. The repetition generator 407 repeats the symbols it receives a predetermined number of times, thus allowing part of the symbols to be lost due to a transmission error without affecting the overall quality of the information being sent. Block interleaver 409 takes the symbols and jumbles them. The long code generator 411 receives the jumbled symbols and scrambles them using a pseudorandom noise sequence generated at a predetermined chip rate. Each symbol is XOR-ed with one of the pseudorandom chips of the scrambling sequence.

The information may be transmitted using more than one carrier (channel) as explained with regards to the method, above. Accordingly, demultiplexer (DEMUX) 511, shown in Figure 5a, takes the input signal "a" and splits it into multiple output signals in such a way that the input signal may be recovered. As shown in Figure 5b, in one embodiment the signal "a" is split into three separate signals, each signal representing a selected data-type, and is transmitted using one FL channel per data-type signal. In another embodiment, DEMUX 511 as shown in Figure 5c splits signal "a" into two components per data-type. Regardless of the arrangement, the present invention contemplates that distinct signals generated from a parent signal can be transmitted using one or more channels.

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Further, this technique can be applied to multiple users whose signals are transmitted using completely or partially the same FL channels. For

example, if the signals from four different users are going to be sent using the same three FL channels, then each of these signals is "channelized" by demultiplexing each signal into three components, where each component will be sent using a different FL channel. For each channel, the respective signals are multiplexed together to form one signal per FL channel. Then, using the technique described herein, the signals are transmitted. Returning to Figure 5a, the demultiplexed signal is then encoded by Walsh encoder 513 and spread into two components, components I and Q, by multiplier 517. These components are summed by summer 519 and communicated to a mobile station (not shown) by transmitter 521.

Figure 5d illustrates a functional block diagram of an exemplary embodiment of the transmission system of the present invention embodied in a wireless communication device 500. One skilled in the art will understand that certain functional blocks shown in the figure may not be present in other embodiments of the invention. The block diagram of Figure 5e corresponds to an embodiment consistent for operation according to the TIA/EIA Standard IS-95C, also referred to as IS-2000, or cdma2000 for CDMA applications. Other embodiments of the present invention are useful for other standards including Wideband CDMA (WCDMA) standards as proposed by the standards bodies ETSI and ARIB. It will be understood by one skilled in the art that owing to the extensive similarity between the reverse link modulation in the WCDMA standards and the reverse link modulation in the IS-95C standard, extension of the present invention to the WCDMA standards may be accomplished.

In the exemplary embodiment of Figure 5d, the wireless communication device transmits a plurality of distinct channels of information which are distinguished from one another by short orthogonal spreading sequences as described in the U.S. Patent Application Serial No. 08/886,604, entitled "HIGH DATA RATE CDMA WIRELESS COMMUNICATION SYSTEM," assigned to the assignee of the present invention and incorporated by reference herein. Five separate code channels are transmitted by the wireless communication device: 1) a first supplemental data channel 532, 2) a time multiplexed channel of pilot and power control symbols 534, 3) a dedicated control channel 536, 4) a second supplemental data channel 538 and 5) a fundamental channel 540. The first supplemental data channel 532 and second supplemental data channel 538 carry digital data which exceeds the capacity of the fundamental channel 540 such as facsimile, multimedia applications, video, electronic mail messages or other forms of digital data. The multiplexed channel of pilot and power control symbols 534 carries pilots symbols to allow for coherent demodulation of the data channels by the base station and power control bits to control the energy of transmissions of the base station or base stations in communication with wireless communication device 500. Control channel 536 carries control information to the base station such as modes of operation of wireless communication device 500, capabilities of wireless communication device 500 and other necessary signaling information. Fundamental channel 540 is the channel used to carry primary information from the wireless communication

device to the base station. In the case of speech transmissions, the fundamental channel 540 carries the speech data.

Supplemental data channels 532 and 538 are encoded and processed for transmission by means not shown and provided to modulator 526. Power control bits are provided to repetition generator 522, which provides repetition of the power control bits before providing the bits to multiplexer (MUX) 524. In MUX 524 the redundant power control bits are time multiplexed with pilot symbols and provided on line 534 to modulator 526.

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Message generator 512 generates necessary control information messages and provides the control message to CRC and tail bit generator 504. CRC and tail bit generator 504 appends a set of cyclic redundancy check bits which are parity bits used to check the accuracy of the decoding at the base station and appends a predetermined set of tail bits to the control message to clear the memory of the decoder at the base station receiver subsystem. The message is then provided to encoder 516, which provide forward error correction coding upon the control message. The encoded symbols are provided to repetition generator 518, which repeats the encoded symbols to provide additional time diversity in the transmission. The symbols are then provided to interleaver 520 that reorders the symbols in accordance with a predetermined interleaving format. The interleaved symbols are provided on line 536 to modulator 526.

Variable rate data source 502 generates variable rate data. In the exemplary embodiment, variable rate data source 502 is a variable rate speech encoder such as described in U.S. Patent No. 5,414,796, entitled "VARIABLE RATE VOCODER," assigned to the assignee of the present invention and incorporated by reference herein. Variable rate vocoders are popular in wireless communications because their use increases the battery life of wireless communication devices and increases system capacity with minimal impact on perceived speech quality. The Telecommunications Industry Association has codified the most popular variable rate speech encoders in such standards as IS-96, IS-127, and IS-733. These variable rate speech encoders encode the speech signal at four possible rates referred to as full rate, half rate, quarter rate or eighth rate according to the level of voice activity. The rate indicates the number of bits used to encode a frame of speech and varies on a frame by frame basis. Full rate uses a predetermined maximum number of bits to encode the frame, half rate uses half the predetermined maximum number of bits to encode the frame, quarter rate uses one quarter the predetermined maximum number of bits to encode the frame and eighth rate uses one eighth the predetermined maximum number of bits to encode the frame.

Variable rate date source 502 provides the encoded speech frame to CRC and tail bit generator 504. CRC and tail bit generator 504 appends a set of cyclic redundancy check bits which are parity bits used to check the accuracy of the decoding at the base station and appends a predetermined set of tail bits to the control message in order to clear the memory of the decoder at the base station.

The frame is then provided to encoder 506, which provides forward error correction coding on the speech frame. The encoded symbols are provided to repetition generator 508, which provides repetition of the encoded symbol. The symbols are then provided to interleaver 510 and reordered in accordance with a predetermined interleaving format. The interleaved symbols are provided on line 540 to modulator 526.

In the exemplary embodiment, modulator 526 modulates the data channels in accordance with a code division multiple access modulation format and provides the modulated information to transmitter (TMTR) 530, which amplifies and filters the signal and provides the signal through duplexer 528 for transmission through an antenna. In IS-95 and cdma2000 systems, a 20 ms frame is divided into sixteen sets of equal numbers of symbols, referred to as power control groups. The reference to power control is based on the fact that for each power control group, the base station receiving the frame issues a power control command in response to a determination of the sufficiency of the received reverse link signal at the base station.

Figure 5e illustrates a functional block diagram of an exemplary embodiment of modulator 526 of Figure 5d. The first supplemental data channel data is provided on line 532 to spreading element 542 which covers the supplemental channel data in accordance with a predetermined spreading sequence. In the exemplary embodiment, spreading element 542 spreads the supplemental channel data with a short Walsh sequence (++--). The spread

data is provided to relative gain element 544, which adjusts the gain of the spread supplemental channel data relative to the energy of the pilot and power control symbols. The gain adjusted supplemental channel data is provided to a first summing input of summing element 546. The pilot and power control multiplexed symbols are provided on line 534 to a second summing input of summing element 546.

Control channel data is provided on line 536 to spreading element 548 which covers the supplemental channel data in accordance with a predetermined spreading sequence. In the exemplary embodiment, spreading element 548 spreads the supplemental channel data with a short Walsh sequence (++++++++--------). The spread data is provided to relative gain element 550, which adjusts the gain of the spread control channel data relative to the energy of the pilot and power control symbols. The gain adjusted control data is provided to a third summing input of summing element 546. Summing element 546 sums the gain adjusted control data symbols, the gain adjusted supplemental channel symbols and the time multiplexed pilot and power control symbols and provides the sum to a first input of multiplier 562 and a first input of multiplier 568.

The second supplemental channel is provided on line 538 to spreading element 552 which covers the supplemental channel data in accordance with a predetermined spreading sequence. In the exemplary embodiment, spreading element 552 spreads the supplemental channel data with a short Walsh

sequence (++--). The spread data is provided to relative gain element 554, which adjusts the gain of the spread supplemental channel data. The gain adjusted supplemental channel data is provided to a first summing input of summer 556.

The fundamental channel data is provided on line 540 to spreading element 558 which covers the fundamental channel data in accordance with a predetermined spreading sequence. In the exemplary embodiment, spreading element 558 spreads the fundamental channel data with a short Walsh sequence (++++----++++----). The spread data is provided to relative gain element 560 that adjusts the gain of the spread fundamental channel data. The gain adjusted fundamental channel data is provided to a second summing input of summing element 556. Summing element 556 sums the gain adjusted second supplemental channel data symbols and the fundamental channel data symbols and provides the sum to a first input of multiplier 564 and a first input of multiplier 566.

In the exemplary embodiment, a pseudonoise spreading using two different short PN sequences (PN_I and PN_Q) is used to spread the data. In the exemplary embodiment the short PN sequences, PN_I and PN_Q, are multiplied by a long PN code to provide additional privacy. The generation of pseudonoise sequences is well known in the art and is described in detail in U.S. Patent No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM," assigned to

the assignee of the present invention and incorporated by reference herein. A long PN sequence is provided to a first input of multipliers 570 and 572. The short PN sequence PN_I is provided to a second input of multiplier 570 and the short PN sequence PN_Q is provided to a second input of multiplier 572.

The resulting PN sequence from multiplier 570 is provided to respective second inputs of multipliers 562 and 564. The resulting PN sequence from multiplier 572 is provided to respective second inputs of multipliers 566 and 568. The product sequence from multiplier 562 is provided to the summing input of subtractor 574. The product sequence from multiplier 564 is provided to a first summing input of summing element 576. The product sequence from multiplier 566 is provided to the subtracting input of subtractor 574. The product sequence from multiplier 568 is provided to a second summing input of summing element 576.

The difference sequence from subtractor 574 is provided to baseband filter 578. Baseband filter 578 performs necessary filtering on the difference sequence and provides the filtered sequence to gain element 582. Gain element 582 adjusts the gain of the signal and provides the gain-adjusted signal to upconverter 586. Upconverter 586 upconverts the gain adjusted signal in accordance with a QPSK modulation format and provides the unconverted signal to a first input of summing element 590.

The sum sequence from summing element 576 is provided to baseband filter 580. Baseband filter 580 performs necessary filtering on difference sequence and provides the filtered sequence to gain element 584. Gain element 584 adjusts the gain of the signal and provides the gain-adjusted signal to upconverter 588. Upconverter 588 upconverts the gain adjusted signal in accordance with a QPSK modulation format and provides the upconverted signal to a second input of summing element 590. Summing element 590 sums the two QPSK modulated signals and provides the result to a transmitter (not shown).

Turning now to Figure 6a, a functional block diagram of selected portions of a base station 600 in accordance with the present invention. Reverse link RF signals from the wireless communication device 500 (Figure 5e) are received by receiver (RCVR) 602, which downconverts the received reverse link RF signals to an baseband frequency. In the exemplary embodiment, receiver 602 down converts the received signal in accordance with a QPSK demodulation format. Demodulator 604 then demodulates the baseband signal. Demodulator 604 is further described with reference to Figure 6b below.

The demodulated signal is provided to accumulator 606. Accumulator 606 sums the symbol energies of the redundantly transmitted power control groups of symbols. The accumulated symbol's energies are provided to de-interleaver 608 and reordered in accordance with a predetermined de-interleaving format. The reordered symbols are provided to decoder 610 and

decoded to provide an estimate of the transmitted frame. The estimate of the transmitted frame is then provided to CRC check 612 which determines the accuracy of the frame estimate based on the CRC bits included in the transmitted frame.

In the exemplary embodiment, base station 600 performs a blind decoding on the reverse link signal. Blind decoding describes a method of decoding variable rate data in which the receiver does not know a priori the rate of the transmission. In the exemplary embodiment, base station 600 accumulates, deinterleaves and decodes the data in accordance with each possible rate hypothesis. The frame selected as the best estimate is based on quality metrics such as the symbol error rate, the CRC check and the Yamamoto metric.

An estimate of the frame for each rate hypothesis is provided to control processor 616 and a set of quality metrics for each of the decoded estimates is also provided. Quality metrics that may include the symbol error rate, the Yamamoto metric and the CRC check. Control processor selectively provides one of the decoded frames to the remote station user or declares a frame erasure.

An expanded functional block diagram of an exemplary single demodulation chain of demodulator 604 is shown in Figure 6b. In the preferred embodiment, demodulator 604 has one demodulation chain for each

information channel. The exemplary demodulator 604 of Figure 6b performs complex demodulation on signals modulated by the exemplary modulator 604 of Figure 6a. As previously described, receiver (RCVR) 602 downconverts the received reverse link RF signals to a baseband frequency, producing Q and I baseband signals. Despreaders 614 and 616 respectively despread the I and Q baseband signals using the long code from Figure 5d. Baseband filters (BBF) 618 and 620 respectively filter the I and Q baseband signals.

Despreaders 622 and 624 respectively despread the I and Q signals using the PN_I sequence of Figure 5e. Similarly, despreaders 626 and 628 respectively despread the Q and I signals using the PN_Q sequence of Figure 5e. The outputs of despreaders 622 and 624 are combined in combiner 630. The output of despreader 628 is subtracted from the output of despreader 624 in combiner 632. The respective outputs of combiners 630 and 632 are then Walsh-uncoverers in Walsh-uncoverers 634 and 636 with the Walsh code that was used to cover the particular channel of interest in Figure 5e. The respective outputs of the Walsh-uncoverers 634 and 636 are then summed over one Walsh symbol by accumulators 642 and 644.

The respective outputs of combiners 630 and 632 are also summed over one Walsh symbol by accumulators 638 and 640. The respective outputs of accumulators 638 and 640 are then applied to pilot filters 646 and 648. Pilot filters 646 and 648 generate an estimation of the channel conditions by determining the estimated gain and phase of the pilot signal data 534 (see

Figure 5d). The output of pilot filter 646 is then complex multiplied by the respective outputs of accumulators 642 and 644 in complex multipliers 650 and 652. Similarly, the output of pilot filter 648 is complex multiplied by the respective outputs of accumulators 642 and 644 in complex multipliers 654 and 656. The output of complex multiplier 654 is then summed with the output of complex multiplier 650 in combiner 658. The output of complex multiplier 656 is subtracted from the output of complex multiplier 652 in combiner 660. Finally, the outputs of combiners 558 and 660 are combined in combiner 662 to produce the demodulated signal of interest.

Figure 7 compares the spectrum of a 1X reverse link spectrum to a 3X reverse link spectrum.

Despite the specific foregoing descriptions, ordinarily skilled artisans having the benefit of this disclosure will recognize that the apparatus discussed above may be implemented in a machine of different construction without departing from the scope of the present invention. Similarly, parallel methods may be developed. As a specific apparatus example, one of the components such as summing element 622, shown in Figure 6b, may be combined with summing element 626 even though they are shown as separate elements in the functional diagram.

OTHER EMBODIMENTS

While there have been shown what are presently considered to be preferred embodiments of the invention, it will be apparent to those skilled in

the art that various changes and modifications can be made without departing from the scope of the invention as defined by the appended claims.

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WHAT IS CLAIMED IS: